Practicing the Protocols

Purpose

To have students:

1. learn how to use each of the hydrology instruments correctly
2. explore the ranges of measurements possible with each instrument
3. use each instrument as directed in the protocol
4. understand the importance of quality control.

Overview

Groups of students will rotate among measurement stations for each of the protocols that will be performed by the class. They will practice using the instrument or kit and protocol for that particular measurement, exploring sources of variation and error. The activity concludes with students testing water samples brought from a variety of places (home, yard, puddles, brooks, etc.).

If you have enough instruments and kits, you may want to focus on a subset of the measurements during a given class period in order to simplify the discussion.

Time

Three to four class periods

Level

Varies with the protocol

Key Concepts

Quality assurance
Quality control
Reliability
Accuracy
Protocol
Calibration

Skills

Following directions carefully
Performing measurements

Materials and Tools

Refer to the *Hydrology Protocols* for the instruments, equipment and kits required for each protocol.

One bucket of tap water

Copies of Hydrology Investigation Student Activity Sheets

In addition you will need the following materials for particular protocols:

Transparency: green food color, spoonful of silt

pH: samples of vinegar water, distilled water, milk, juice, soda pop, etc.

Temperature: ice

Conductivity: distilled water, salt

Salinity: distilled water, salt, ice

Nitrate: lawn fertilizer

Preparation

Ask students to bring in water samples from the home and/or yard.

Set up measurement stations for each of the protocols your students will be performing. For each station you will need:

Equipment and instruments to perform the measurement

One copy of the protocol to be posted at the station

Copies of the Hydrology Investigation Student Activity Sheet.

Draw a bucket of tap water at the beginning of the day and allow it to sit until class. Record the time on a piece of tape attached to the bucket.

Fill a Dissolved Oxygen sample bottle at the same time and preserve the sample as directed in the protocol. Record the time on the sample bottle label.

Prerequisites

None

Background

A quality assurance and quality control (QA/QC) plan is necessary to ensure test results are as accurate and precise as possible. Accuracy refers to how close a measurement is to true value. Precision means the ability to obtain consistent results. Desired accuracy, precision and reliability are ensured by:

- careful calibration, use, and maintenance of testing equipment
- following the specific directions of a protocol exactly as described
- repeating measurements to ensure that they are within acceptable limits
- minimizing contamination of samples, stock chemicals and testing equipment
- keeping track of samples.

Together these steps help make the data you collect valid, valuable and meaningful.

Calibration

Calibration is a procedure used to check the accuracy of testing equipment. To assure that the equipment is functioning properly, a solution of known value is tested. Calibration procedures vary among the measurements and are detailed in each protocol.

Safety

Consult Material Science Data (MSDS) sheets that come with the kits and buffers. Also consult your local school district's safety procedure guidelines.

What To Do and How To Do It

1. Divide the students into small groups, optimally three per group. Checking each others work, students should take turns reading directions, making measurements, and recording the data.
2. Students rotate through each station learning the instruments and protocols.
3. Reconvene the class. For each measurement:

   3.1. Plot all the data points as a way of helping students visualize the concept of precision. When measurements are precise, points are close together. Discuss the range of measurements found and variations among the measurements.

   3.2.Brainstorm with students the issue of why there are discrepancies. This is the time to bring up calibration against standards, reliability, accuracy, and adherence to protocols. Connect explanations with reasons for specific steps in the protocols. Stress the importance of making accurate measurements so they can compare different samples.
4. Compare the results they obtained on samples from various places. Help them make sense of their results by placing data on a map of the water sources and considering the history of each sample in terms of well water, city water, pool, pond, puddle or brook. This is also a good time to stress the importance of accurate measurements when you make comparisons. Is the difference real or measurement error? This is also the time to discuss why we didn't test these samples for DO and temperature and how we might test for them.

Adaptations

Beginning students

Focus on one measurement at a time, following the outline given above.

Advanced students

Have students create their own data plots and interpret them.

Further Investigations

Repeat the above explorations but vary one parameter-such as temperature by cooling one third of each water sample, and heating one third of the water samples, with the remaining one third at room temperature. Then compare the effect of water temperature on the other measurements.

Hydrology Investigation
Student Activity Sheet

Transparency Station
Background

Transparency is the measurement of water clarity. How clear the water is at your site will depend on the amount of soil particles suspended in the water and on the amount of algae or other growth at your site. Transparency may change seasonally with changes in growth rates, in response to precipitation runoff, or for other reasons. The clarity of your water determines how much light can penetrate. Since plants require light, transparency becomes an important measurement in determining productivity of your water site.

In the field you would measure transparency in one of two ways; with a Secchi disk in deep, still waters or with a turbidity tube if your site has shallow or running water. For the lab practice station, we will use the turbidity tube.

What To Do and How to Do It

1. Ask each student to fill the turbidity tube with tap water until the image disappears. Record the depth of the water in the tube in cm.
2. Compare data from several students. Ask students to formulate hypotheses on variations in their data.
3. Try the tube again testing variables such as: amount of light in the room, tube in sunlight and shadow, with and without sunglasses, turning the tube to try and detect the image at the bottom, letting the water stand in the tube for 15-20 seconds.
4. Once students have established the depth using tap water, pour the water into a bucket and mix a few grams of silt into the water.
5. Ask students to fill the turbidity tube with the silty water until the image disappears. Record the depth of the water in the tube in cm. Compare the readings from several students.
6. Put a few drops of green food coloring in tap water.
7. Have each student fill the turbidity tube with colored water until the image disappears.

Student	Sample Tested	cm

Hydrology Investigation
Student Activity Sheet

Temperature Station

Background

Water temperature is the temperature of a body of water such as a stream, river, pond, lake, well, or drainage ditch as it appears in nature. Water bodies can vary greatly in temperature, according to latitude, altitude, time of day, season, depth of water, and many other variables. Water temperature is important because it plays a key role in chemical, biological and physical interactions within a body of water. For example, high temperatures may be an indicator of increased plant production. The temperature of the water determines what aquatic plants and animals may be present since all species have their natural limits of tolerance to upper and lower temperatures. Water temperature can therefore help us to understand what may be happening within the water body without directly measuring hundreds of different things within the body of water.

What To Do and How To Do It

1. Following the steps in the *Water Temperature Protocol*, each member of the group should take a turn measuring the temperature of the same sample with the same thermometer. Make sure everyone in the group can read the thermometer. Compare your readings. Are they within 0.5° C of each other? Why? Why not? If not, repeat this exercise with another water sample until you are obtaining readings within 0.5° C of each other.
2. With each member of the team using a different thermometer and following the steps of the water temperature protocol, measure the temperature of a single water sample and compare your readings. Do you get readings within 0.5° C of each other? Why? Why not? If not, your thermometers may need calibration.
3. Following the steps in the water temperature protocol, measure the temperatures of water from the hot and cold water taps, ice water, and the water that has been standing in the bucket.
   List the things you checked and record the temperatures you obtained for them.
4. Discuss the range of measurements possible with each of the thermometers.
   Can you take temperatures below the freezing mark? Why? Why not?
   Can you take the temperature of boiling water with the thermometer provided? Why? Why not?

Student	Sample Tested	Temperature

Hydrology Investigation

Student Activity Sheet

Dissolved Oxygen Station

Background

All living things depend on oxygen to survive. In a water environment molecules of oxygen gas dissolve in the water. This is called dissolved oxygen (DO). In air, 20 out of every 100 molecules are oxygen. In water, only 1-5 molecules out of every million molecules are oxygen. This is why dissolved oxygen is measured in parts per million (ppm). Different species of aquatic organisms require different amounts of oxygen, but generally aquatic organisms require at least 6 ppm for normal growth and development.

Water temperature and altitude influence how much oxygen water can hold; i.e., the "equilibrium" value. In general, warmer water cannot hold as much oxygen as colder water. Similarly, at higher altitudes water cannot hold as much oxygen as waters at lower altitudes. Look for these patterns in the Temperature and Altitude Tables in the DO protocol. This is why we use a distilled water standard in the protocol and correct for temperature and altitude.

The actual amount of DO in a water may be higher or lower than the equilibrium value. Bacteria in the water consume oxygen as they digest decaying plant or animal materials. This can lower the DO levels of the water. In contrast, algae in lakes produce oxygen during photosynthesis which can sometimes result in higher DO levels in summer.

What To Do and How To Do It

1. Following the steps in the *Dissolved Oxygen Protocol*, each member of the group takes a turn measuring the DO of the same sample. Compare your readings. Are they within 0.2 mg/L of each other? Why? Why not? If not, repeat this exercise with another water sample until you obtain readings within 0.2 mg/L of each other.
2. If your water faucets have aerators on them, test a water sample freshly drawn from the faucet, one that was drawn at the beginning of the day and allowed to sit undisturbed in a bucket, and the preserved sample drawn at the same time. Record the time at which you tested the water in the bucket. How long has it been since the water was drawn? Compare the readings. Are they different? Why? Why not? What might account for the differences?

Student	Sample tested	Time	DO

Hydrology Investigation
Student Activity Sheet

pH Station

Background

pH is an indicator of the acid content of water. The pH scale ranges from 1 (acid) to 14 (alkaline or basic) with 7 as neutral. The scale is logarithmic so a change of one pH unit means a tenfold change in acid or alkaline concentration. For instance, a change from 7 to 6 represents a solution 10 times more acidic; a change from 7 to 5 is 100 times more acidic, and so on. The lower the pH the more acidic the water. The pH of a water body has a strong influence on what can live in it. Immature forms of salamanders, frogs, and other aquatic life are particularly sensitive to low pH.

What To Do and How To Do It

1. Following the steps for pH paper in the *pH Protocol*, each member of the group takes a turn measuring the pH of the same sample. Compare your readings. Are they within 1.0 pH units of each other? Why? Why not? If not, repeat this exercise with another water sample until you are obtaining readings within 1.0 pH units of each other.
2. Without calibrating the pH pen, but following the steps for the pen given in the *pH Protocol*, take turns measuring the pH of a different water sample. Record these numbers.
3. Calibrate the pH pen and repeat the measurements again following the protocol carefully to avoid contaminating samples. Alternatively, students could use one calibrated pen and one that has not been calibrated if there is enough equipment. Record your readings.
4. Compare the data obtained using different methods. Discuss possible reasons for the differences.
5. Take the pH of familiar liquids such as distilled water, vinegar, tap water, milk, juice, soda pop, etc. using pH paper, uncalibrated pH pens, and calibrated pH pens.
6. List the samples you checked and record the pH obtained by the different methods. Which methods gave the most accurate results? The most reliable?
7. Create a pH scale and plot the average values obtained for each sample.

Sample tested	pH paper	uncalibrated pH pen	calibrated pH pen

Hydrology Investigation
Student Activity Sheet

Electrical Conductivity Station

Background

Electrical conductivity is a measure of the ability of a water sample to carry an electrical current. Pure water is a poor conductor of electricity. It is the impurities in water, such as dissolved salts, that enable water to conduct electricity. Therefore, conductivity is often used to estimate the amount of dissolved solids in the water since it is much easier than evaporating all the water molecules from a sample and weighing the solids that remain.

Conductance is measured in a unit called the microSiemen/cm. Sensitive plants can be damaged if they are watered with water that has electrical conductivity levels above about 2200-2600 microSiemens. For household use, we prefer water with conductivity below 1100 microSiemens. Manufacturing, especially of electronics, requires pure water.

What To Do and How To Do It

1. Following the steps in the *Electrical Conductivity Protocol*, each member of the group takes a turn measuring the conductivity of the same tap water sample. Compare your readings. Are they within 40 µSiemens/cm of each other? Why? Why not? If not, repeat this exercise with another water sample until you are obtaining readings within 40 µSiemens/cm of each other.
2. Without calibrating the electrical conductivity pen, but following the steps of the protocol, take turns measuring the conductivity of distilled water, tap water, and distilled water to which you have added a pinch of salt. Record those numbers.
3. Calibrate the pen and repeat the measurements following the protocol carefully to avoid contaminating samples. Record your readings below.
4. Compare the data obtained using the uncalibrated pen and the calibrated pen. Is there a difference? Discuss possible reasons for the differences. Is one pen always higher or lower than the other? By the same amount?
5. Measure the conductivity of familiar liquids such as vinegar, drinking water, milk, juice, soda pop, etc.

   List the samples you checked and record the results.
6. What is the range of conductivity readings? Create a conductivity scale and plot the value obtained for each sample.

Sample tested	uncalibrated conductivity pen	calibrated conductivity pen
distilled water		
tap water		
salty water		

Hydrology Investigation
Student Activity Sheet

Salinity Station - for Salt or Brackish Water

Background

Salinity is the measurement of dissolved salts in salty or brackish water. It is measured in parts per thousand (ppt). Salinity may vary with precipitation, snow melt, or proximity to a freshwater source such as a river mouth.

The hydrometer is an instrument which measures the specific gravity or density of a fluid. Its design is based on the principle, recognized by the Greek mathematician Archimedes, that states that the weight loss of a body in a liquid equals the weight of the liquid displaced. The denser your liquid, therefore, the less the weighted bulb must sink to displace its own weight.

Why do you need to take a temperature reading with your hydrometer reading? Water becomes more dense as it approaches freezing - then less dense as it becomes ice. Since we want to measure the effect of dissolved salts on density, we must control the temperature variable.

What To Do and How To Do It

1. Fill a 500 mL cylinder with fresh water to the 500 mL line.
2. Gently place the hydrometer into the cylinder (do not drop).
3. Read the scale on the hydrometer at the bottom of the meniscus. Record.
4. Remove the hydrometer and add 7.5 grams of salt to the cylinder. Stir.
5. Use a thermometer to measure the temperature in the cylinder 10 cm below the surface. Record.
6. Use the hydrometer to measure the density of the fluid in the cylinder. Record.
7. Look up the salinity of your fluid from the table using the temperature and hydrometer readings. Record.
8. Add 10 grams of salt to your mixture.
9. Measure the temperature and salinity of the fluid. Record.
10. Add a few pieces of ice to the cylinder.
11. Measure the temperature and salinity of the fluid. Record.

Examine the data which you have recorded. The salinity of fresh water should be 0. As you add salt to the water, the salinity should increase. Changing the temperature will affect the density of the water, but should not affect the salinity after the conversion is done.

Discuss any variations between students. Repeat the measurements if variations exceed 2 ppt.

Work Sheet for Salinity Station

Sample	Temperature	Hydrometer	Salinity	Student/s
Fresh water				
7.5 grams salt				
17.5 grams salt				

Hydrology Investigation

Student Activity Sheet

Alkalinity Station

Background

Alkalinity is a measure of the ability of a body of water to resist changes in pH when acids are added. Acid additions generally come from rain or snow, although soil sources may also be important in some areas. Alkalinity is generated when water dissolves rocks such as calcite and limestone. The alkalinity of natural waters protects fish and other aquatic organisms from sudden changes in pH.

What To Do and How To Do It

1. Following the steps in the *Alkalinity Protocol*, each member of the group takes a turn measuring the alkalinity of the same sample of tap water. Compare your results. Are they within one drop or titrator unit of each other? Why? Why not? If not, repeat this exercise with another tap water sample until you are obtaining results within one drop or titrator unit.
2. Test the water samples you have brought to class from other sources.

   List the source of the water sample and the results obtained. Compare the alkalinity of these samples. What is the range of results? Why are there variations?

Student	Sample tested	Reading

Hydrology Investigation
Student Activity Sheet

Nitrate Station

Background

Nitrogen is one of the three major nutrients needed by plants. Most plants cannot use nitrogen in its molecular form (N_2). In aquatic ecosystems blue-green algae are able to convert N_2 into ammonia (NH_3) and nitrate (NO_3^-) which can then be used by plants. Animals eat these plants to obtain nitrogen that they need to form proteins. When the plants and animals die, protein molecules are broken down by bacteria into ammonia. Other bacteria then oxidize the ammonia into nitrites (NO_2^-) and nitrates (NO_3^-). Under suboxic conditions nitrates can then be transformed by other bacteria into ammonia (NH3), beginning the nitrogen cycle again.

Typically nitrogen levels in natural waters are low (below 1 ppm nitrate nitrogen). Nitrogen released by decomposing animal excretions, dead plants, and animals is rapidly consumed by plants. In water bodies with high nitrogen levels eutrophication can occur. Nitrogen levels can become elevated from natural or human-related activities. Ducks and geese contribute heavily to nitrogen in the water where they are found. Man-made sources of nitrogen include sewage dumped into rivers, fertilizer washed into streams or leached into groundwater, and runoff from feedlots and barnyards.

Nitrate levels are measured in milligrams per liter nitrate nitrogen.

What To Do and How To Do It

1. Following the steps in the *Nitrate Protocol*, measure the nitrate level of the water sample. Compare the readings of several students. Are they within 0.2 mg/L of each other? If not, discuss possible reasons for error. Repeat the readings until you obtain readings within 0.2 mg/L.
2. Repeat the protocol with the same water, but shake the sample for half of the time given in the protocol.
3. Repeat the protocol with the same water, but leave the sample to set for five minutes beyond the time given in the protocol.
4. Measure the nitrate level in a number of different water samples: runoff from a golf course, other pond water, a stock tank, river, etc. List the sources of water and record your results.
5. Add a few grains of fertilizer to your sample. Test again. What is the difference?
6. Discuss possible sources of nitrogen in your water samples.

Sample Tested	Reading	Student